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(54) Image forming device and two-dimensional optical scanning device.

(57) Described are an image forming device and a two-dimensional optical scanning device. The image forming device comprises an electro-optic effect light valve (120) including a photoconductive material (102) and an electro-optic medium (101), means (106) for applying a recording electric field to said light valve, means (105) for inputting an image to said photoconductive material, and means for reading out an image from said light valve, and is characterized in that in said light valve (120) the electro-optic medium (101) undergoes a state-transition in response to a photoelectric conversion action of said photoconductive material (102). A preferred image input means is a two-dimensional optical scanning device, comprising a light beam generating means, a rotating polygon-mirror deflector for effecting deflective scanning of light beams output by said light beam generating means, a condensing optical means for focusing the light beams on a scanned plane to form an image, and a movable mirror linearly movable within a specified plane for reflecting the light beams deflected by said rotating polygon-mirror deflector into a direction at a given angle, wherein a scanning length lp, the length of stroke ls of said linear movable mirror, an angle ($\alpha/2$) formed between said movable mirror and the specifi d plane, and an angle β formed between said scanned plane and the specified plane satisfy the following two formulae:

$$lp/\sin d\alpha = ls/\sin d\beta$$
$$\alpha + 2\beta = \pi .$$

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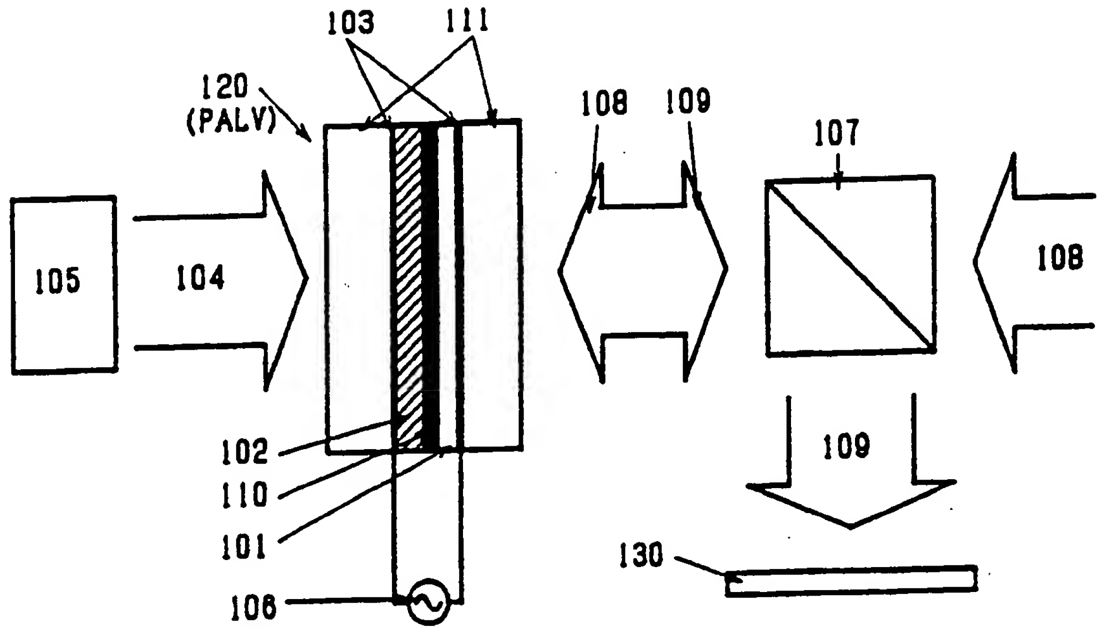

FIG. 1

IMAGE FORMING DEVICE AND TWO-DIMENSIONAL OPTICAL SCANNING DEVICE

This invention is directed generally to an optical scanning device for effecting two-dimensional scanning of laser beams and an image forming device as well, and more particularly, to a device for forming an optically inputted two-dimensional image and a recording method therefore.

A conventional image forming device is typified by an electronic device disclosed in JP-A-216126/1984 or a device using thermoplastic as a medium to be modulated. As reported in SID 87 DIGEST p.367 (1987) and SID 85 DIGEST p.260 (1985), an image formed by a light valve employing a smectic A (hereinafter abbreviated to SmA) liquid crystal is recorded on photosensitive paper or other material.

Besides, as in the case of a device reported in vol. 27, No.1, p.20 (1975), the NHK Technical Institute, a prior art two-dimensional scanning device requires a multiplicity of highly accurate anamorphic lenses. This is because scanning corrections are performed with respect to a horizontal deflection and a vertical deflection, respectively, these corrections being represented by corrections of a curvature aberration of field and of an image surface inclination of a polygon-mirror. A vector scan type of a two-dimensional scanning device based on a galvano-mirror requires a special focal point correcting means for correcting the curvature aberration of field.

A great majority of conventional optical image storing devices utilize thermooptic effects in which the storage of an input image can not be controlled electronically. This presents a problem of requiring much time to form the image. A problem associated with the electronic driving is a deterioration of an electro-optic medium. An additional problem is that there is no simple and highly accurate means for inputting the image.

Accordingly, the present invention aims at irradiating photoconductive material with the light beams for image input, providing a novel driving method and forming a highly accurate image at a high velocity. This invention further aims at providing more sophisticated functions of a display and a printer, etc. It is another object of this invention to provide both a two-dimensional optical scanning device for simple and high quality raster scanning and an image forming device using this two-dimensional optical scanning device.

These objects are achieved with an image forming device as claimed in claim 1 and a two dimensional optical scanning device as claimed in claim 36, respectively. Preferred embodiments of the invention are subject matter of dependent claims.

The present invention will hereinafter be described in detail by way of embodiments and with reference to drawings in which:

Fig. 1	is a block diagram illustrating an image forming device of the present invention;
Fig. 2	is a sectional view depicting a light valve;
Fig. 3	is a side elevation showing a device for recording an image formed in the PALV on a photosensitive medium by effecting two-dimensional scanning of a laser beam;
Fig. 4	is a perspective view depicting a two-dimensional optical scanning device of this invention, including a control system;
Fig. 5	is a diagram showing a geometric relation of scanning beams;
Figs. 6, 7, 8(a), 8(b) and 8(c)	are diagrams each showing an example of a driving signal waveform for the light valve;
Figs. 9(a) through 9(c)	are diagrams each illustrating a driving waveform in a recording method wherein an erasing method is applied;
Fig. 10	is a block diagram depicting a control system of the two-dimensional optical scanning device;
Fig. 11	is a block diagram illustrating a system for handling a video signal;
Fig. 12	is a time chart showing a sequence when recording an image;
Fig. 13	is a diagram illustrating a driving waveform of a positive pulse alone and another driving waveform of a negative pulse alone;
Fig. 14	is a conceptual diagram showing a logic operation of a two-dimensional image;
Fig. 15	is a diagram showing a driving waveform of th logic operation of th two-dimensional imag ;
Fig. 16	is a characteristic diagram of the operation of th PALV;
Figs. 17(a) through (d)	are diagrams of examples of logic operations on a complicated two-dimensional image on the basis of sequential operations, Figs. 17(a) and

17(b) showing a logic "A AND (NOT B)", and Figs. 17(c) and 17(d) showing an Exclusive OR (EX.OR);

Fig. 18 is a chart showing an operating principle of a color image forming device; and

Fig. 19 is a diagram illustrating a basic configuration of a complex machine consisting of a display and a printer.

Embodiment 1

Fig. 1 is a block diagram illustrating an image forming device of this invention. The numeral 120 designates an electro-optic effect light valve (hereinafter referred to as PALV). A chiral-smectic C liquid crystal 101 (hereinafter referred to as an SmC*liquid crystal) is defined as an electro-optic medium having a bistability. The bistable states of the SmC* liquid crystal 101 are controlled by an electric field applied between electrodes 103 through a photoconductive material 102. The electric field is applied to the transparent electrodes 103 from a recording electric field applying means 106. Designated at 104 is an image beam inputted to the photoconductive material from image inputting means 105. The numeral 107 represents a polarization beam splitter (hereinafter abbreviated to PBS) constitutinga means for reading a recorded image. The PBS 107 separates a read-out beam 108 from an image beam 109. A photosensitive medium 130 is irradiated with the image beam 109, thereby effecting a recording process. In this embodiment, a PALV image is formed on the photosensitive medium by use of a projection optical system. A printer and a hard copy device are thus actualized. The photosensitive medium involves the use of materials reported in SID 87 DIGEST p.367 (1987). Other available materials are mediums and dry silver paper mentioned in SID 85 DIGEST p. 260 (1985). If a screen is disposed in place of the photosensitive medium, a display unit is provided. Indicated at 110 is a read-out beam blocking means for preventing the photoconductive material from undergoing an influence from the read-out beam. The numerals 111 denote transparent substrates. Table 1 shows further details of this embodiment.

Table 1

Image inputting means	Image forming projection of image beam or two-dimensional scanning of laser beam
Recording electric field applying means	Pulse generator
Image reading means	He-Ne laser beam, PBS
PALV	
Photoconductive material	High-resistance a-Si containing trace quantity B (by plasma CVD method
Bistable medium	SmC* liquid crystal (CS-1015 made by Chisso Corporation) SiO_2 oblique vapor deposition alignment, approximately 2μm in thickness

Electrod	ITO transpar nt electrode
Read-out beam blocking means	Dielectric mirror (multilayer film of Si, SiO_2)
Substrat	Corning 7059 glass substrate
Photosensitive medium	Cycolor recording paper (Cycolor is a trademark of Mead Co.)

An oblique vapor deposition film is used as an alignment film. Liquid crystal molecules are thereby oriented at approximately 30° inclined to the substrate surface. In this embodiment, deposition is effected from a direction tilted at 85° to the normal of the substrate. As a result, when using the liquid crystal molecules having a positive refractive index anisotropy (Δn), apparent Δnd is reduced (d is the thickness of the liquid crystal layer). For this reason, the thickness d can be increased to optimize the contrast with an increment of the apparent Δnd. Namely, the liquid crystal layer can be increased in thickness. Hence, in the case of employing a conventional organic high polymer orientation film, an optimum condition is developed when $d = 1\mu m$ or thereabouts. Whereas in the present invention, the optimum condition can be found out when $d = 2\mu m$ or thereabouts. As can be observed from a sectional view of a light valve in Fig. 2 liquid crystal molecules 201 are tilted. Therefore, when the read-out beam is incident on a substrate 202 from a vertical direction, an apparent director tilt angel Θm (larger than a true tilt angle 203) becomes large. This enhances the brightness and contrast as well. A way of combining the two substrates is demonstrated by Fig. 2, wherein deposition directions of deposition films 204 need reversely paralleled to each other. The deposition films 204 need not necessarily be provided on both of the two substrates. Other materials of the oblique vapor deposition film exhibit the same function if they are insulating substances which can be deposited.

In this embodiment, the temperature of the liquid crystal layer is constantly controlled to keep the response time and the alignment property.

The following is a description of a way of forming a laser beam undergoing two-dimensional scanning which is mentioned in Table 1 as one possibility for the image input. Fig. 3 is a side elevation depicting a device for recording an image formed in the PALV on a photosensitive medium. This image is obtained by effecting the two-dimensional scan of the laser beam in directions X-Y and performing image inputting in the PALV. Designated at 302 is a polygon scanner for effecting horizontal scanning with a write beam. An X-Y scan is effected with the beam together with a linear movable mirror 305 movable in directions of an optical axis of a lens within a horizontal polarization plane. A means for moving the linear movable mirror involves the use of a servo motor 309 including a highly accurate cross roller table and a ball screw joined thereto in this embodiment. The servo motor performs positioning by an output of an encoder serving as a position detecting means. Moving means other than that shown in this embodiment are, as a matter of course, adoptable on the condition that these means are controllable. A semiconductor laser (hereinafter referred as LD) 308 generates the write beam. The numeral 301 represents a condensing lens group; 310 a PALV disposed on a plane to be scanned; 303 a polarization beam splitter for detecting the polarization; and 304 a read-out beam. Scanning beams are focused on the PALV, thereby forming pixels according to the scanning beam. The number of the scanning beams is not limited in the writing system. A PALV image is formed and transcribed on a screen or a photosensitive medium 311, by an image beam 307 reading from the PALV.

Fig. 4 is a perspective view illustrating a two-dimensional optical scanner of this invention, including a control system. The numeral 401 represents a synchronous detector for horizontal scanning, 402 a synchronous detector for vertical scanning and 403 a control circuit. A vertical initial node is detected by a mechanical position detecting method or a photodetecting method which utilizes a leakage beam of the scanning beams. Scanning signals are transmitted to a linear movable mirror driving unit 404 in synchronism with the two synchronous signals 409 from detectors 401 and 402. Image data 407 is transferred to a light beam modulation means 406. A method of synchronizing the synchronous signals, PALV driving signals and reference signals will be mentioned later. The PALV is disposed on the plane to be scanned, and the scanning beams are focused on the PALV. As a result, the pixels according to the scanning beams are formed. Fig. 4 illustrates a so-called pre-objective scanning optical system in which a rotating polygon-mirror deflector 412 is positioned on the side of a light source with respect to the condensing lens group

411.

Light beams emitted from the light beam modulating means 406 are polarized by the rotating polygon-mirror deflector 412 in the horizontal direction. Next, the polarized beams pass through the lens group 411 for correcting an image surface inclination and condensing the beams. The beams are then incident on the linear movabl mirror 415. The beams, whose direction is changed by the linear movable mirror, are focused on the scann d plan 416. Fig. 5 is a diagram showing a geometrical relationship. A tilt angle ($\alpha/2$) 509 of the linear movable mirror 415 and a tilt angle β 510 of the scanned plane are set as shown in the formulae (1) and (2) so as not to change the length of the light path of the scanning beam with respect to the scanned plane 508 irrespective of a position of the mirror 415.

$$lp/\sin\alpha = ls/\sin\beta \quad (1)$$
$$\alpha + 2\beta = \pi \quad (2)$$

where lp 501 is the effective scanning length, and ls 502 is the length of the stroke of the linear movable mirror. Further details of the main components are given in Table 2.

Table 2

Name of component	Specifications
Rotating polygon-mirror	6 surfaces 6000 rpm
Lens group	one group of 3 lenses: a positive lens, a cylindrical lens and a negative lens (details of the lenses are shown in Table 3)
Linear movable mirror	tilt angle ($\alpha/2$) = 30° stroke 30 mm increment reflection type surface mirror
Scanned plane	tilt angle β = 60°

Table 3 shows an example of manufacturing numerical values of the lens group.

Table 3

Surface No.	Curvature Rm	Curvature Rs	Int r-face distance	Reflective index
1	---	---	45	1
2	150	150	10	1.511
3	-45.71	-45.71	0	1
4	∞	∞	2	1.511
5	∞	-27,23	10	1
6	-41.15	-41.15	2	1.767
7	-100	-100	229	1

unit: mm

Caution) . Initial image forming distance Sm = -587
. Rm and Rs are radii of curvatures of a meridional plane and a saggital plane
. The first surface is a reflection surface of the rotating polygon-mirror

The horizontal scanning optical system in this embodiment is not limited to this scanning system but may include typical scanning systems. The usable optical systems are disclosed in, for instance, JP-A-13461/1984 and "Optics" Vol.10 (1981), the 56th issue, p.348. This scanning optical system is capable of correcting the image surface inclination of the rotating polygon-mirror. It is therefore possible to restrain vertical deflections of the horizontally scanned beams to a smaller degree. Intervals between the horizontally scanned beams undergo almost no influence by angular deflections of the linear movable mirror by using a slider having a high accuracy and the foregoing cross roller table as well. This embodiment makes the most of characteristics of the optical system for correcting the image surface inclination. Hence, this embodiment exhibits an advantage of obtaining a hyperfine raster image. This type of laser scanning system similarly functions even by employing not only the PALV of this invention but also a PALV using smectic A liquid crystal reported in Appl. Phys. Lett., vol.21, p.392 (1972) and a PALV using nematic liquid crystal reported in SID 77 digest, p.106 (1977).

Next, a method of recording the image on the PALV will be described. In this embodiment, an AC electric field synchronized with screen scanning is employed as a recording electric field. The image beams are inputted synchronized therewith. Fig. 6 is a diagram illustrating a typical driving signal waveform. The symbol V_{PALV} 601 represents a driving voltage impressed on the PALV; and LD_{SIGNAL} 602 a light emitting signal of a semiconductor laser. The signal V_{PALV} is an AC signal synchronized with a scanning cycle (1H) 603 of a polygon-scanner. One frame 604 contains an erasing signal 605 and a write driving signal 606. No signal is given during a hold period 607. An index signal 608 serves to take a synchronism with the scanning cycle 1H. Table 4 shows specifications used in this embodiment.

Table 4

Polygon scanner		
	Number of r volutions	6000 rpm
	Number of surfaces	6 surfaces
	Scanning cycle	1.67 msec
V_{PALV}		
	Erasion	
	Level	20V to -20V
	Frequency	1.2 kHz
	Application pulse number	corresponding to 4 cycles
	Write	
	Level	10V to -10V
	Period (frequency)	1.167 msec (6kHz)
	Duty	50 %
	Hold	
	Level	0V or open circuit
	LD_{SIGNAL}	
	Modulation frequency	4 MHz
	Active period	1.67/20 msec

Referring to Table 4, the frequency of V_{PALV} is set at 6 kHz, while the duty thereof is set to 50 %. Requirements of adoptable duties and frequencies are that a synchronous relationship between the polygon scanner and the scanning cycle is established, and a write region of the PALV can effectively horizontally be scanned. For example, as illustrated in Fig. 7a, the erasing pulses are set corresponding to one cycle, while the active period of LD_{SIGNAL} can be allocated to all the negative cycles of V_{PALV}. A series of fundamental write processes will be explained considering the above-mentioned.

To start with, the erasing signal is inputted during an erasing period to erase the screen. The amplitude Ve of the erasing pulse is set to a value enough to invert the spontaneous polarization of liquid crystal molecules even without laser beam irradiation. Applied for the next write periods t1-tn is an AC recording electric field of the amplitude Vw (Vw is set to a value enough to invert the liquid crystal molecules when photo pulses are applied). During a period for which the recording electric field assumes a positive polarity, photo signals modulated corresponding to the image are inputted to record the image. More specifically, when LD_{SIGNAL} is given to a positive cycle of V_{PALV}, the SmC* liquid crystal can be changed from an S_1 state corresponding to a negative cycle to an S_2 state corresponding to the positive cycle. During the hold period th, i.e. after the write period is terminated, the applied voltage set at 0V. What has been described so far is the principle of the LD beam writing process.

Figs. 8(a) through 8(c) show a method wherein, before and after a write time tw for writing one scanning line a invalid period tm is provided in the recording AC electric field. The period tm allows the PALV to attain a steady state after the change of the polarity of the recording field and prior to the input of the photo signals. This method does not need to irradiate writing beams onto the PALV during the whole writing polarity period. It is provided to maintain the driving by AC voltage. In Fig. 8, for example, a finite period tm

is provided as the invalid period before the writing light is irradiated in the writing polarity period. That is, modulated light signals (LD signal) are applied after V PALV turns to th writing polarity and tm has passed.

The operation mov s to a holding process after finishing th write process. To stabilize a state of the liquid crystal in a holding state, the electric circuit of the electrodes can be opened, or alternatively a high impedance state can be given after finishing write scanning on the entire screen. At this time, the high impedance state is developed between the electrodes while keeping the recording electric field at Vw. Consequently, it is feasible to prevent a state transition caused by applying transient pulses associated with potential variations of V_{PALV} to the liquid crystal layer. After the display, the combination of arranging the liquid crystal in one state and keeping a high impedance allows to prevent a so-called afterimage i.e., the unevenness in display which appears on the screen when writing the next representation.

Note, that for erasing, there are provided a method of applying write beams during a cycle (negative cycle in this case) opposite to that of the writing time and a method of applying erasing beams during a cycle having a polarity opposite to that of writing. In this case, the erasing voltage can be reduced. Besides, partial erasing and partial writing can be performed when making a good use of an erasing mechanism. The partial erasing can be executed by writing pixels during the cycle having a polarity opposite to that of the write time in the sequence of writing of the erasing beams. The partial writing is carried out by applying th write beams during the write time subsequent to the partial erasing. The partial erasing/writing process s have such an advantage that a rewrite time can be reduced as compared with entire erasing and rewriting processes.

Fig. 9 shows a recording method based on the erasing method described above. The whole screen can be erased by the above-mentioned method. The following is a description of a way of writing. A recording electric field waveform shown in Fig. 9(b) is applied between the electrodes in synchronism with an index signal (see Fig. 9(a)) coincident with laser scanning. Applied for the write periods t1 through tn is an AC recording electric field of the amplitude Vw (Vw is a value enough to invert the liquid crystal molecules when applying the photo pulses). A first line (recording period t1) will be explained. During this recording period t1, V_{PALV} consists of a negative and a positive cycle. Inputted for the negative cycle of t1 is a photo signal (data a of Fig. 9(c)) modulated corresponding to a negative of the image. The image equivalent to a half of one scanning line is thereby recorded. Next, when the recording electric field V_{PALV} assumes a positive polarity, during the second cycle of the period t1, a photo signal (data $\bar{a}$ of Fig. 9(c)) modulated corresponding to a positive of the image is inputted. The remaining half of the image is recorded. Thereafter, the next line is scanned by the laser beam. Recording is performed during the recording periods t2 through tn in the same manner. Namely, according to this method, the same scanning line is divided into plural sub-lines, whereby a transition from the S_1 state corresponding to the negative cycle to the S_2 state corresponding to the positive cycle alternately corresponds to another transition from the S_2 state to the S_1 state. These two transitions can be allocated for every scanning line. In V_{PALV} at this time, it is required that the negative and positive of the signal be changed over within each scanning line. This method yields an advantage in that the scanning time is effectively usable.

Next, a system for synchronizing a driving signal with a two-dimensional scanning system will be described. Fig. 10 is a block diagram depicting a control system of the two-dimensional scanning device according to the present invention. As discussed above, the control system of Fig. 10 is needed for performing accurate raster scanning. A controller 1001 including a frame memory has an oscillator 1002 for emitting clock pulses to control the system as a whole. On the other hand, a PLL reference signal within the controller is given by a horizontal scan detecting signal 1004. The signal 1004 is transmitted from an index sensor 1003 defined as a detector for detecting the horizontal scanning cycle. A system clock completely synchronized with horizontal scanning is created from original oscillation clock pulses. A PLL employed herein is composed of a typical comparator, a low-pass filter and a frequency divider. The number of revolutions of the rotating polygon-mirror is applied to the comparator of the PLL by detecting a counter-electromotive force of a brushless motor driving the mirror. Image information to be written is accumulated in the frame memory at any time. A serial signal 1007 read out synchronously with the system clock serves to modulate a semiconductor laser 1005. The numeral 1006 designates a driving circuit of the semiconductor laser. A rotation control signal 1008 for the rotating polygon-mirror 1010 is outputted from the controller 1001 to form a loop of the PLL. The numeral 1009 represents a driving circuit of a rotating polygon-mirror motor. On the other hand, a driving signal 1012 synchronized with the horizontal scanning is transmitted from the controller 1001 to a PALV driving circuit 1013 for a PALV 1011. A frame synchronous signal 1016 is given to the driving circuit 1015 of the servo motor 1014 for effecting Y-scanning in accordance with the frame. Y-scanning is kept in the synchronous relationship by the controller. Note, that a broken line 1017 indicates a laser beam. A two-dimensional image is formed by this control system.

A relationship between a video signal and the two-dimensional optical scanning device will next be

explain d. Fig. 11 is a block diagram illustrating the system. A frame memory 1102 transmits a video signal 1103, a horizontal synchronous signal 1H 1104 and a vertical synchronous signal 1V 1105. On the other hand, a horizontal scan detecting signal 1118 coming from an index sensor 1123 is sent to the controller 1101 as a revolution number signal of the rotating polygon-mirror 1110. The signal 1118 is compared with the horizontal synchronous signal 1104 corresponding to a PLL refer nce signal, thereby controlling a rotation control signal 1108 for the rotating polygon-mirror. Th horizontal scan is thus effected by use of the laser beam completely synchronized with the horizontal synchronous signal. The video signal 1103 undergoes a level conversion into a serial signal to modulate the semiconductor laser 1125. The numeral 1106 stands for a driving circuit for the semiconductor laser. The rotation control signal 1108 for the rotating polygon-mirror 1110 is outputted from the controller to form a PLL loop. Designated at 1109 is a driving circuit for the rotating polygon-mirror motor. A driving signal 1112 synchronized with the horizontal synchronous signal 1104 is given from the controller 1101 to a PALV driving circuit 1113 for a PALV 1111. A frame synchronous signal 1116 is given to a driving circuit 1115 of a servo motor 1114 for performing Y-scanning in accordance with the frame. Consequently the controller keeps the Y-scan in the synchronous relationship with respect to the frame signal. This frame synchronous signal is created from the vertical synchronous signal 1105. Note, that a broken line indicates a laser beam. A two-dimensional image is formed by this control system.

Embodiment 2

An embodiment 2 will deal with an arrangement in which two-dimensional optical image recording is effected on the PALV, and an image forming device employs this image. The PALV has the constitution shown in the Table 1 in the first embodiment. The image forming device is constructed of the PALV, a means for reading the image and an image inputting means such as an ordinary image forming optical system. As discussed in the embodiment 1, the image forming optical system and the photosensitive medium are usable. Fig. 12 is a time chart showing a sequence when recording the image. Fig. 12 shows an image input, an erasing beam input, a driving voltage and a status of a recording device sequentially from the top. The entire photoconductive area is irradiated with the erasing beam to initialize the recording device.

A series of operations executed at respective timings will be described. In Fig. 12, the numeral 1201 indicates positions in which a state of liquid crystal changes. The erasing beam is emitted at a timing t_0. A pulse voltage is supplied at a timing t_1, whereby one stable state S_1 of the SmC* liquid crystal is developed. A letter "A", which has been written, is now erased. The S_1 state is thereafter held till the recording process is initiated. The operation then moves to the recording process. An input image beam is given at a timing t_2. A driving voltage pulse assuming a phase opposite to that at t_1 is given at a timing t_3. At this time, the SmC* liquid crystal of a beam-irradiated portion of the input image "B" transits to a stable state S_2 reverse to S_1. This is an image recording status. So far as the input beam and the driving voltage are not applied thereafter, this image recording status is held. A static driving waveform of the typical SmC* liquid crystal herein serves as a write pulse. However, any kind of pulse capable of switching the bistable state is usable. For instance, the operation is practicable by only positive pulses or negative pulses.

Besides, the partial erasing and writing processes can be done. More specifically, a portion to be erased is irradiated with the erasing beam and the driving pulse for developing the S_1 state is merely given. The previous recording status is held in other portions with no erasing beam. Partial writing is, after finishing the partial erasing process, performed by giving the driving pulse for developing the S_2 state as well as by emitting the writing image beam.

The processes described above can be considered by applying to the electronic circuit. Namely, it is presumed that the two-dimensional image information is conceived as an input signal, and the recording electric field signal is a clock and reset signal. Based on this presumption, the same operation as that of a flip-flop with respect to the two-dimensional information signal can be carried out.

As depicted in Fig. 14, a multiplicity of image inputs are simultaneously given, and the recording electric field signals are applied. At this time, it is possible to effect a logic operation of the two-dimensional image with respect to each image input. Fig. 14 shows an example of 2 input images, i.e., "A" 1401 and "B" 1402. For inputting and outputting the images to a PALV 1403, though not illustrated for simplicity in Fig. 14, the image forming optical system is usable. The numeral 1404 represents an output image in the case of an "OR" operation. The output image 1404 is written to all regions receiving the optical inputs. The numeral 1405 designates an output image in the case of an "AND" operation. Fig. 15 shows a driving method for executing the operation shown in Fig. 14. Referring to Fig. 15, intensities of the two input images of Fig. 14 are indicted by "A" 1501 and "B" 1502. The symbol V_{PALV} represents a driving signal

applied to the PALV. Fig. 16 shows operational characteristics of the PALV. Fig. 16 also shows a relationship between a driving voltage 1602 and a refl ctivity 1603 r pr senting a relative output b am intensity of the PALV, wher in an input beam intensity 1601 is a parameter. The symbols I_1 1606 and I_2 1607 denote input beam intensities select d in this embodiment. The symbol 0· 1608 indicates that the intensity is 0. Similarly, V_1 1604 and V_2 1605 designate selected driving voltages. It can be understood from Fig. 16, that the PALV has a threshold characteristic with respect to the driving voltage, and this threshold shifts depending on the input beam intensity. This characteristic is, it can be consid red, derived from a threshold characteristic of an electro-optic effect. These threshold characteristics are combined to make practicable the logic operation shown in Fig. 14. Referring again to Fig. 16, when the driving voltage is set to the lower voltage side driving voltage V_1 1604, the reflectivity can be controlled by the input beam intensity. This is no more than the "AND" operation by which th reflectivity is allowed to transit to a higher level only in the high intensity portion where the input beams are overlapped. Fig. 15(a) shows a driving method based on this operation. In this case, the input beam intensity is set at the level I_1 1607, wherein the input beam intensity is not allowed to change the PALV state. Next, the input beam intensity is inputt d after setting it at the higher level I_2 1606 wherein the input beam intensity can change the PALV state. As a result, the "OR" operation can be effected, wherein the region to which any one of them is inputted becomes a transistable region. Fig. 15(b) shows this driving method. When the driving voltage is set at the higher level V_2 1605, the threshold of input beam intensity decreases. Hence, even I_1 alone can cause a change, whereby the same "OR" operation can be executed. Fig. 15(c) illustrates an example of this driving method.

The PALV, having a storage ability, is capable of attaining an intricate two-dimensional image logic by sequentially performing the operations. Fig. 17 shows a simple example of the logic. Figs. 17(a) and 17(b) show a logic of "A AND (NOT B)". After writing an input "A" at a positive cycle, "B" is written at a negative cycle. In consequence of this step, a logic "AND" operation in association with "NOT B" is obtained. Figs. 17(c) and 17(d) show a case of an Exclusive OR (Ex. OR). The operation starts with writing "A OR B" by the method shown in Fig. 15(c). Next, the method of Fig. 15(a) is applied to the negative cycle, thereby writinga negation of "A AND B". They are the simplest logics. These logics are further multi-combined to obtain complicated logic operations.

V_{PALV} is herein modulated considering such a controllability that the PALV driving voltage has a quicker response. As illustrated in Fig. 16, however, the threshold characteristic is obtainable by either the driving voltage or the input beam intensity. Therefore, the same result is acquired even when modulating the input beam intensity.

A negative logic conceived as another significant logic is, as explained referring to Figs. 7(c) and 7(d), obtained simply by writing during the reversed polarity cycle. The negative logic is obtained further by a method of effecting polarizing rotations by a read optical system and by a polarization rotating elem nt (e.g., a $\lambda/2$ plate and a twisted liquid crystal element, etc.)

The explanation of the erasing process is herein omitted for simplicity. The erasing process may be executed by the method described in Fig. 12 or by applying a high voltage pulse enough to cause a transition with no input beam, which is explained in the embodiment 1.

A dielectric mirror is provided in the recording device, preventing the read-out beam from influencing the photoconductive material, and it is therefore possible to read a recording status serving as output image information at any time. This separation or blocking mirror can be omitted. This process is practicable in such a manner that the read-out beam irradiation timing is not overlapped with the driving pulse, and it undergoes no influence by the read-out beam during the state transition. With this arrangement, a transmission read type recording device is attainable.

Besides, the erasing beam may also be eliminated. The reason for this is that the beam for reducing an impedance of the photoconductive material during the state transition is not necessarily required. For example, in a dark state, a pulse of an amplitude larger than the write pulse amplitude can be appli d, whereby erasing can be done. Given to the photoconductive material is a structure having a commutating property in the dark state like a PIN structure. The SmC* liquid crystal is put into the erasing state S1 by the forward pulse. The erasing process can also be performed by this method. The image can be written by the same way as that in the case of the above-mentioned bipolarity.

The thus formed image can be transcribed on the photosensitive medium.

The writing method in the embodiment 2 is, it can be considered, intended to replace the spot scan image in the embodiment 1 by a two-dimensional image. The logic, described in the embodiment 2, between the incident beams is therefore practicable similarly with the write beam image in the embodiment 1. This is effective in a write process by use of, e.g., write beams having different diameters, in write processes in different beam scanning directions and in a logic between the two-dimensional image input

beam and the scanning beam. In this case, an available beam scanning method may be a raster scan or a vector scan.

Embodiment 3

The embodim nt 3 concerns a case where this invention is applied to a color image forming device as an example of an image forming device.

As discussed in the embodiments 1 and 2, an image is sequentially written by a pixel unit or a two-dimensional unit, whereby the PALV is capable of forming and erasing an image at a high speed as well as effecting partial erasing/writing processes thereof. The embodiment 1 has already touched on the image forming device in which the PALV is used for a secondary image. In the embodiment 3, the color image forming device is put into practice by making a good use of this arrangement.

The following is a description of a principle of the color image forming device. A read-out beam wavelength is restricted to output image information which differs depending on the wavelength. The image information is recorded on the photosensitive medium. Note, that the basic configuration is the same as that of the embodiment 1 of Fig. 1. The PALV has also the same construction as that of the embodiment 1. Fig. 18 is a chart showing the operating principle of the color image forming device for recording three images on the photosensitive medium by using read-out beams having three different wavelengths or wavelength regions. A series of processes consists of operating processes 1807, 1808 and 1809 corresponding to the respective images. Each operating process is composed of a recording period 1815 with a corresponding one of wavelengths λ_1, λ_2 and λ_3, and an output period 1816 of the image beam. During the recording period 1815, as explained earlier, erasing is effected by an erasing pulse 1817. Subsequently, the image is recorded by synchronously applying a write pulse 1818 of V_{PALV} 1814 and an image input beam 1810. During the output period 1816, the PALV is irradiated with the read-out beam 1804, 1805 and 1806 corresponding to the images 1801, 1802 and 1803 respectively. The image beams having different wavelengths fall on the photosensitive medium. In the embodiment 3, the read-out beam involves the use of a halogen lamp beam traveling through a wavelength selecting filter. Three filters are changed over corresponding to the respective output periods. Fig. 18 shows a case where the three images are obtained in the three recording output sequences with the three wavelengths. The number of sequences is not limited to 3. For example, if the sensitivity of the photosensitive medium extends over the whole visible region, the images which differ according to red, green and blue are given to the P_{ALV}. The images are read by the method described above, and it follows that the photosensitive medium acquires full-color information. It is preferable that a spectrum outputted from the PALV at this time is set equally to a modulation spectrum possessed by the photosensitive medium. That is, a red PALV output beam is given for red coloring of the photosensitive medium. The reason for this is that the object body is illuminated with th light, and the write beam emerging from the object body can also be given to the photosensitive medium. When recording the images on the photosensitive medium through the PALV, however, the spectrum of the beam written to the PALV is not necessarily equalized to that of the PALV output beam. Namely, there is no problem if the spectrum of the image beam 1801 shown in Fig. 18 differs from that of the corresponding read-out beam 1804. Similarly, there is also no problem if that spectrum is different from a coloring spectrum of the photosensitive medium. Those spectra can be set independently.

When recording the image directly on a photosensitive medium having a low sensitivity, this requires a large power of illumination beams. Ordinary substances have diffusive characteristics of reflection. The larger power of illumination beams is also needed from this point of view. In the case of employing the PALV, the image beam coming from the object body is temporarily recorded on the PALV. It follows that the writing process can be effected long on the photosensitive medium with a small illumination light source. The PALV exhibits high sensitive photoelectric converting action with the aid of a photoconductive material. The PALV is therefore capable of writing with a beam of extremely faint light and reading the image with a beam having a high intensity. In other words, this utilizes image amplifying action by the PALV. Besides, the PALV is able to control an electric field. Hence, there can be added a function to control the foregoing inter-image process and the fluctuations in the write beam quantity as well.

Note that the erasing beam is not illustrated in Fig. 18. This is because the light for reducing the impedance of the photoconductive material is not necessarily needed during the state transition. In Fig. 18, a pulse of an amplitude larger than the write pulse amplitude is given in the dark state, and rasing is carried out. Given to the photoconductive material is a structure such as a PIN structure having a commutating property in the dark state. This may be attained by a method of bringing the SmC* liquid crystal in the erasing state S_1 with a forward pulse.

The image beams may be inputted to the PALV on the basis of the beam scanning shown in the

mbodiment 1 or the two-dim nsional image input shown in the embodim nt 2. Besides, a inputting method utilizing a combination ther of is also usable.

Embodiment 4

The embodiment 1 has dealt with the arrangement in which the PALV is capable of forming and erasing the image at a high velocity as well as effecting the partial erasing/writing processes by sequentially writing the spot or area pixels. Embodiment 4 will present an example of an image formingdevice incorporating complex functions including a display function, a printer function and a copying machine function.

Fig. 19 shows an example of a complex machine constructed of a display and a printer. A method of inputting the image to the light valve is the same as with the embodiment 1. Therefore, only an image read-out unit will be explained. A half-mirror 1901 defined as a read-out beam distributing means is interposed between a projection lens 1904 and a screen 1903. The PALV image detected by a polarization beam splitter (PBS) is split into two subbeams. One subbeam of the image beam is projected on the screen 1903 for display, while the other subbeam is projected on a photosensitive medium 1902 for a page printer. The image can thereby be printed simultaneously when displaying the image information. In the embodiment 4, the half-mirror is disposed on the read-out beam side. There is, however, a method of writing the imag directly on sensitized paper with the distributed write beams by providing the half-mirror on the write beam side. An additional method is that time sharing is executed to distribute the image beams to the display and the printer.

Added to the write system of the PALV is an optical system of the copying machine, i.e., the image inputting optical system shown in the embodiment 2. With this arrangement, a single machine is capable of compactly incorporating three functions, viz., a page display function, a color page printer and a color copying machine.

The embodiments have been described so far, and the present invention can be conceived as an electronic film electrically controllable by the driving electric field. Hence, this invention is, as a space modulation element, widely applicable not only to the embodiments discussed above but also to electronic image devices, image display systems, image registers and optical arithmetic units.

As described above, the present invention exhibits the following advantages. The electronically controlled two-dimensional image can be formed. The recording functions thereof can be obtained. This invention has general purposes in which both of the reflection type image inputting means and the transmission type image inputting means are usable irrespective of the two-dimensional input and the scanning input.

The image formed is read out to the photosensitive medium. This yields an advantage in which the image can be recorded on the photosensitive medium at a high speed. An additional advantage is that th inter-image process is executed, and its result can be outputted.

A width of selecting the sensitivity of the photosensitive medium and the photosensitive wavelength characteristic is increased owing to the amplifying action of the light valve and the wavelength converting characteristic. The optimization thereof can thus be attained. In the case that the image is depicted with highly accurate beams, the width of selecting sensitivity serves to expand a degree of freedom of selecting the light beam source when forming the image on the light valve. It is possible to provide the small-sized image forming device having a high reliability and a high efficiency.

The oblique vapor deposition film is employed as a liquid crystal orientation film, thereby improving the contrast and the brightness as well. The AC drive can be actualized in driving the light valve and in the write method. A deteriorationin the liquid crystal serving as an electro-optic medium is restrained, thus obtaining the high reliability. Recording is performed by using the positive and negative polarities during the recording period. As a result, the necessity for the erasing period is eliminated, and the recording electric field can be transformed into an AC field. Besides, the drive for making partial rewriting possible becomes practicable because of the partial erasing recording process.

Furthermore, a logic operation between the input beams can be performed, and hence the image can be functionally processed.

The basic logic element in the parallel image process can be provided.

As explained above, it is feasible to provide the light-valve-based compact image forming device which, as a single unit, incorporates the functions of the page display, color page printer and full-color copying machine.

The one-dimensional optical scanning device typified by the polygon-mirror scanning device can be put into practice. Besides, the two-dimensional optical scanning device can be also put in operation simply by adding the linear movable mirror to the corresponding optical system and the focusing optical system

without changing an image forming status. There is no necessity for adding a complicated anamorphic lens and a focal point corr cting m chanism. For this reason, it is possible to provide the two-dimensional optical scanning device and the image forming device at lower costs.

According to the present invention, the high-speed two-dimensional optical scanning d vice exhibiting a high accuracy and a complete synchronous relationship can thus be actualized.

Claims

1. An image forming device comprising
an electro-optic effect light valve (120) including a photoconductive material (102) and an electro-optic medium (101),
means (106) for applying a recording electric field to said light valve,
means (105) for inputting an image to said photoconductive material, and
means for reading out an image from said light valve,
characterized in that in said light valve (120) the electro-optic medium (101) undergoes a state-transition in response to a photoelectric conversion action of said photoconductive material (102).

2. The device according to claim 1, wherein said light valve (120) forms the image by use of an electro-optic medium exhibiting a bistable characteristic.

3. The device according to claim 1 or 2, wherein the electro-optic effect of said electro-optic medium exhibits a threshold characteristic with respect to a voltage applied to it.

4. The device according to claim 3, wherein the electro-optic effect of said electro-optic medium exhibits a threshold characteristic with respect to the voltage applied to it and with respect to the intensity of an input beam from said imaging inputting means (105).

5. The device according to claim 3, wherein the electro-optic effect of said electro-optic medium exhibits a threshold characteristic with respect to a driving voltage of said light valve.

6. The device according to claim 2, wherein said electro-optic medium is a dielectric liquid crystal, an oblique vapor deposition film composed of an inorganic oxide being formed on a surface contiguous to said liquid crystal of at least one of two substrates (111) sandwiching said dielectric liquid crystal therebetween.

7. The device according to any of the preceding claims, wherein said light valve (120) comprises said photoconductive material (102), a read-out beam blocking means (110), the electro-optic medium (101) and electrodes (103).

8. The device according to any of the preceding claims, wherein said image reading means is an image output optical system for outputting the image onto a photosensitive medium (130).

9. The device according to claim 8, wherein said image output optical system irradiates said photosensitive medium (130) with read-out light beams having a plurality of different wavelengths or wavelength regions.

10. The device according to claim 8, wherein the spectrum of said image output optical system is different from the spectrum of a write beam of said image inputting means (105).

11. The device according to claim 1, wherein said image inputting means is a unit for projectively inputting a two-dimensional optical image in synchronism with said recording electric field applying means (106).

12. The device according to claim 11, wherein said two-dimensional optical image inputting means projectively inputs a plurality of two-dimensional optical images in synchronism with said recording electric field applying means (106).

13. The device according to claim 12, wherein said two-dimensional optical inputting means projectively inputs the plurality of two-dimensional optical images in synchronism with a positive or a negative cycle

of said recording electric field.

14. The device according to claim 12, wherein said two-dimensional optical image inputting means projectively inputs in time series the plurality of two-dimensional optical images in synchronism with said recording electric field applying means (106).

15. The device according to claim 1, wherein said image inputting means (105) for inputting an image to said photoconductive material (102) is a two-dimensional optical scanning device synchronized with said recording electric field applying means (106).

16. The device according to claim 15, wherein said two-dimensional optical scanning device includes a light beam generating means (406), a horizontal deflector (412) for effecting horizontal scanning of light beams, a condensing optical means (411) for focusing the light beams onto a scanned plane to form an image, and a vertical optical scanning device for deflecting the light beams deflected by said horizontal deflector (412) in vertical directions.

17. The device according to claim 16, wherein said horizontal deflector (412) comprises a rotating polygon-mirror, and said vertical scanning device comprises a mirror (415) linearly movable within a specified plane for reflecting the light beams deflected by said rotating polygon-mirror into a direction at a giv n angle, wherein a scanning length lp, the length of stroke ls of said movable mirror (415), an angle ($\alpha/2$) formed between said movable mirror and said specified plane, and an angle β formed between said scanned plane and said specified plane satisfy the following two formulae:

$$lp/\sin\alpha = ls/\sin\beta$$
$$\alpha + 2\beta = \pi .$$

18. The device according to claim 16 or 17, wherein the scanning of said two-dimensional optical scanning device is synchronized with a reference signal transmitted from a detecting unit (401) for a horizontal scanning cycle of said horizontal deflector (412).

19. The device according to claim 16 or 17, wherein the scanning of said two-dimensional optical scanning device is synchronized with a reference signal defined as a horizontal synchronous signal transmitted from an image signal source.

20. The device according to claim 18 or 19 wherein a driving signal of said recording electric field applying means is synchronized with said reference signal.

21. The device according to claim 1, wherein a driving signal of said recording electric field applying means is an AC signal comprising within each frame an erasing signal, a write driving signal synchronized with an image input and a hold period.

22. The device according to claim 21, wherein said write driving signal has a portion of a specified polarity corresponding to the writing process, said portion being synchronized with an image beam input from said image inputting means.

23. The device according to claim 22, wherein said write driving signal has a portion of a specified polarity, a part of said portion being synchronized with an image input from said image inputting means.

24. The device according to claim 22, wherein said erasing signal assumes a polarity opposite to that corresponding to writing of said write driving signal during an irradiation by an erasing beam.

25. The device according to claim 21, wherein said erasing signal has an amplitude sufficient for said electro-optic medium to undergo a state transition during non-irradiation by a light beam.

26. The device according to claim 21, wherein said electric field applying means during said hold period is held a high impedance or open circuit state.

27. The device according to claim 21, wherein said electro-optic medium transits to or is held in any one of th states, just before the hold period.

28. The device according to claim 1, wherein a driving signal applied by said recording electric field applying means to said light valve is an AC signal consisting of a write driving signal assuming a first polarity synchronized with a positive image input and a write driving signal assuming a second polarity opposite to said first polarity synchronized with a negative image input.

29. The device according to claim 1, wherein a beam intensity of said image inputting means comprises a first intensity level sufficient to change the state of the light valve and a second intensity level requiring the summed intensity of a plurality of input beams to change the state of the light valve.

30. The device according to claim 1, wherein a driving signal applied by said recording electric field applying means to said light valve comprises a first voltage level at which the intensity of a single input beam is sufficient to change the state of the light valve and a second voltage level at which only the summed intensity of a plurality of input beams can change the state of light valve.

31. The device according to claim 1, wherein said image read-out means is an image inputting means to said photoconductive material of said light valve.

32. The device according to claim 1, wherein said image read-out means is an image output optical system for outputting an image to a screen.

33. The device according to claim 1, wherein said image read-out means outputs the same image or a mirror image.

34. The device according to claim 33, wherein said image read-out means outputs the same image or a mirror image to said photosensitive medium and a screen.

35. A two-dimensional optical scanning device, comprising
a light beam generating means, a rotating polygon-mirror deflector (412) for effecting deflective scanning of light beams output by said light beam generating means, a condensing optical means (411) for focusing the light beams on a scanned plane to form an image, and a movable mirror (415) linearly movable within a specified plane for reflecting the light beams deflected by said rotating polygon-mirror deflector into a direction at a given angle, wherein a scanning length lp, the length of stroke ls of said linear movable mirror (415), an angle ($\alpha/2$) formed between said movable mirror and the specified plane, and an angle β formed between said scanned plane and the specified plane satisfy the following two formulae:

$$lp/\sin\alpha = ls/\sin\beta$$
$$\alpha + 2\beta = \pi .$$

36. The device according to claim 35, wherein said condensing optical system includes an optical system for correcting the degree of parallelism of a rotary axis with each mirror of said polygon-mirror.

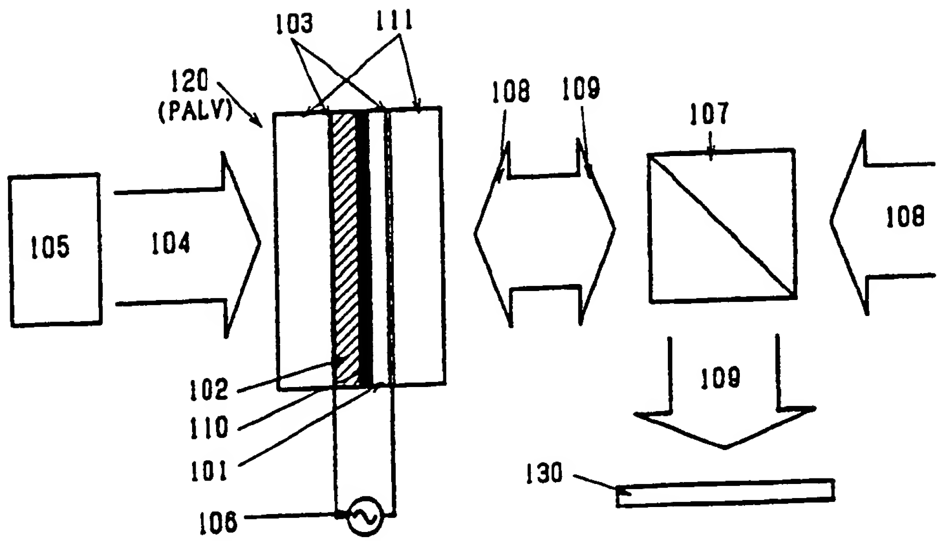
103
111
120
(PALV)
108
109
107
105
104
108
109
102
110
101
106
130

FIG. 1

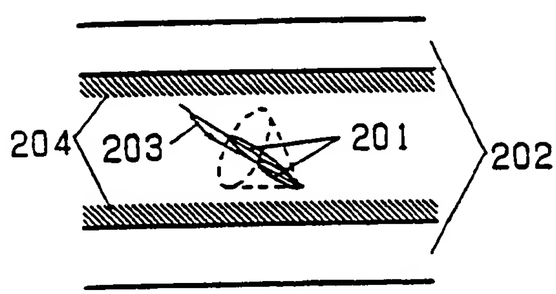
204
203
201
202

FIG. 2

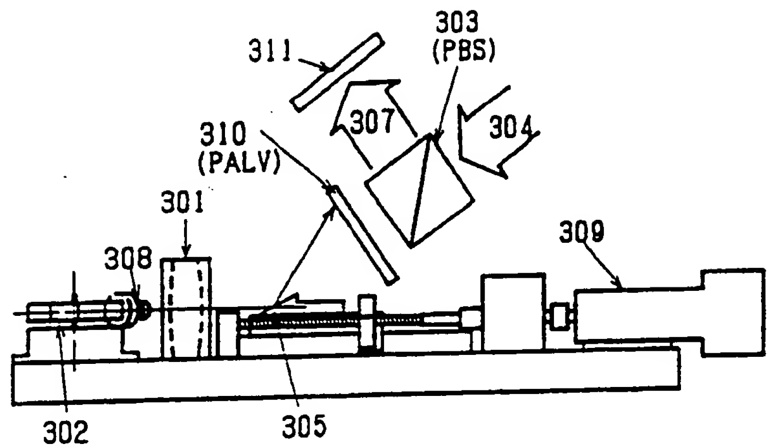
311
303
(PBS)
307
304
310
(PALV)
301
308
309
302
305

FIG. 3

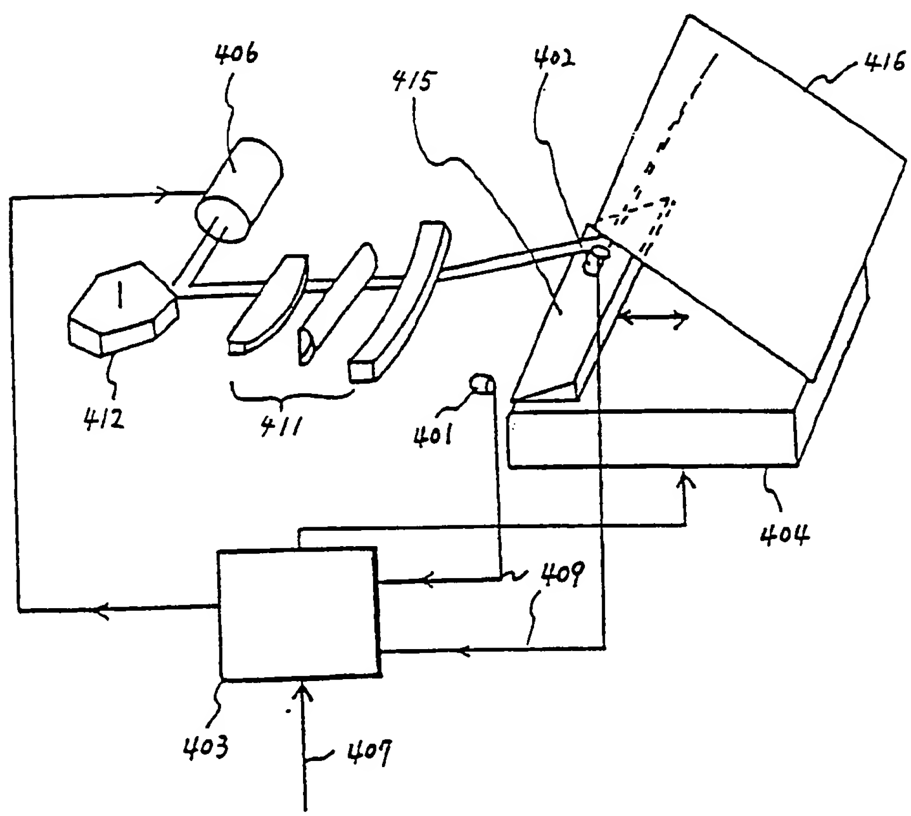
406
415
402
416
412
411
401
404
409
409
403
407

FIG. 4

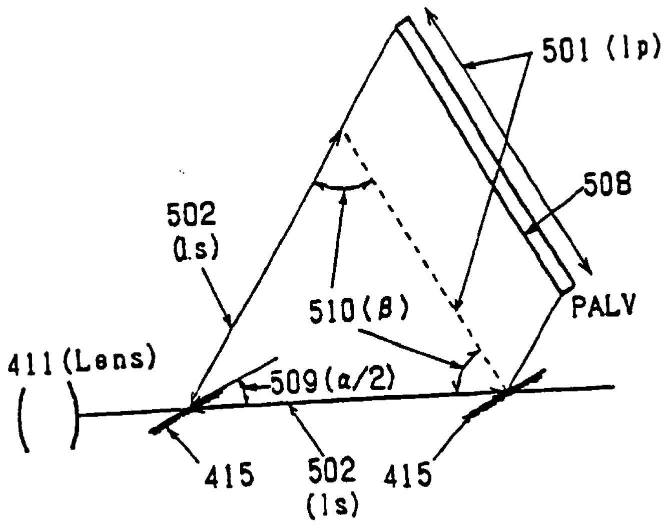
501 (Ip)
508
502
(Ls)
510 (β)
PALV
411 (Lens)
509 (α/2)
415
502
(Is)
415

FIG. 5

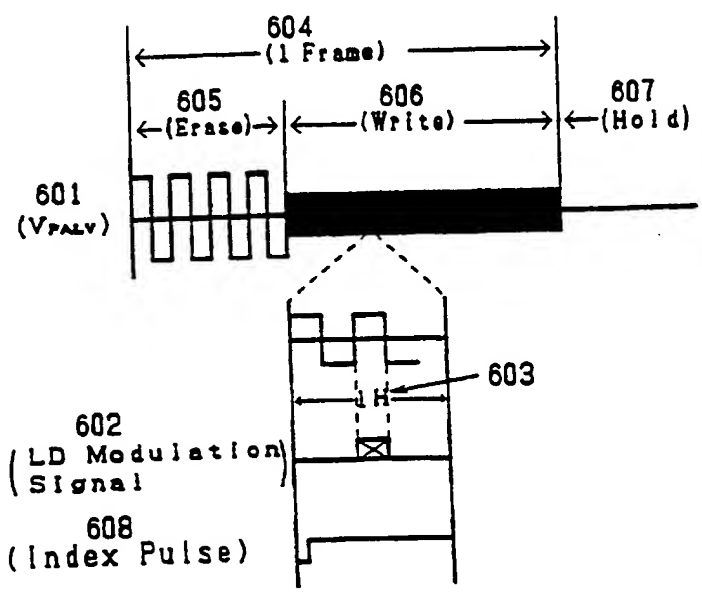
604
(1 Frame)
605
(Erase)
606
(Write)
607
(Hold)
601
(VPALV)
603
1 H
602
(LD Modulation Signal)
608
(Index Pulse)

FIG. 6

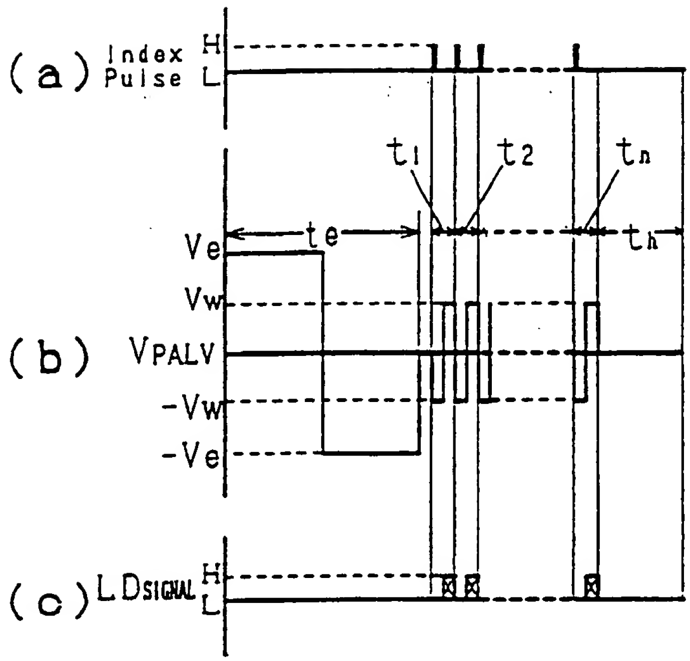
(a) Index Pulse
H
L
t1
t2
tn
Ve
te
th
Vw
(b) VPALV
-Vw
-Ve
(c) LDSIGNAL
H
L

FIG. 7

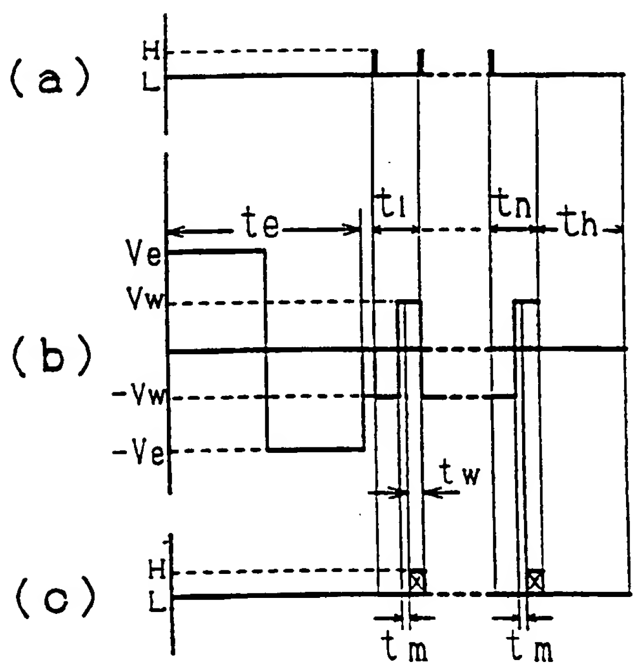
(a)
H
L
te
t1
tn
th
Ve
Vw
(b)
-Vw
-Ve
tw
(c)
H
L
tm
tm

FIG. 8

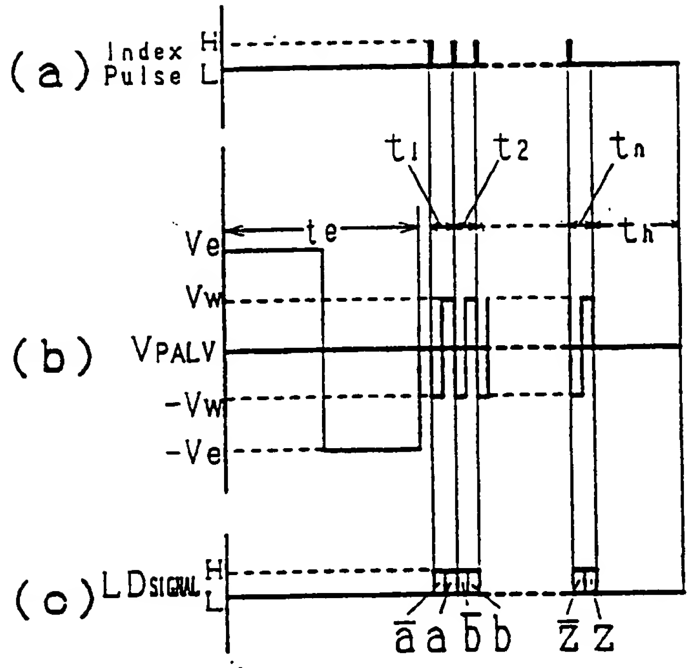
(a) Index Pulse
H
L
(b)
Ve
Vw
VPALV
-Vw
-Ve
te
t1
t2
tn
th
(c) LDSIGNAL
H
L
ā a b̄ b
z̄ z

FIG. 9

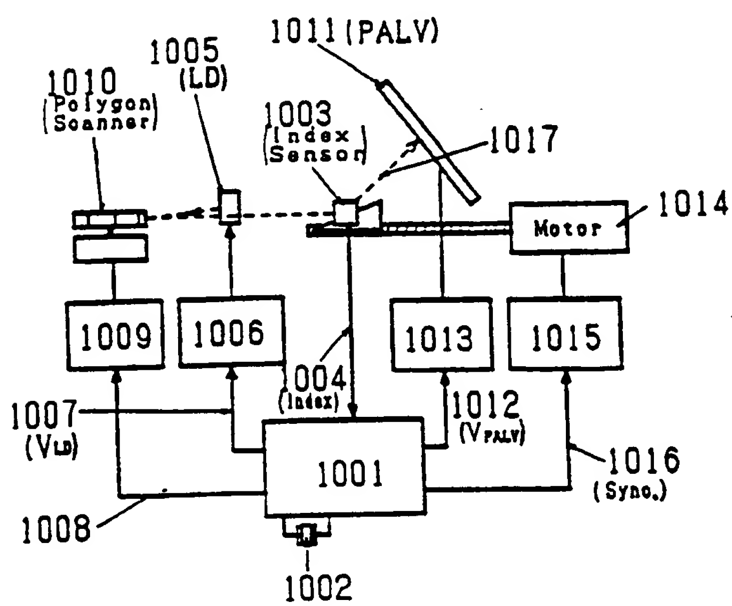
1011 (PALV)
1005 (LD)
1010 (Polygon Scanner)
1003 (Index Sensor)
1017
1014
Motor
1009
1006
1013
1015
1004 (Index)
1007 (VLD)
1012 (VPALV)
1001
1016 (Sync.)
1008
1002

FIG. 10

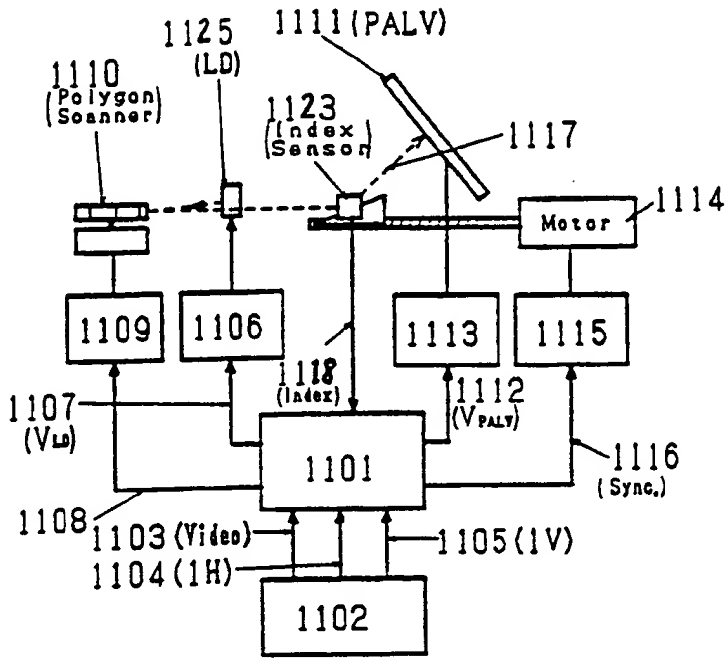
1110
(Polygon Scanner)
1125
(LD)
1111 (PALV)
1123
(Index Sensor)
1117
Motor
1114
1109
1106
1113
1115
1118
(Index)
1107
(VLD)
1112
(VPALV)
1101
1116
(Sync.)
1108
1103 (Video)
1104 (1H)
1105 (1V)
1102

FIG. 11

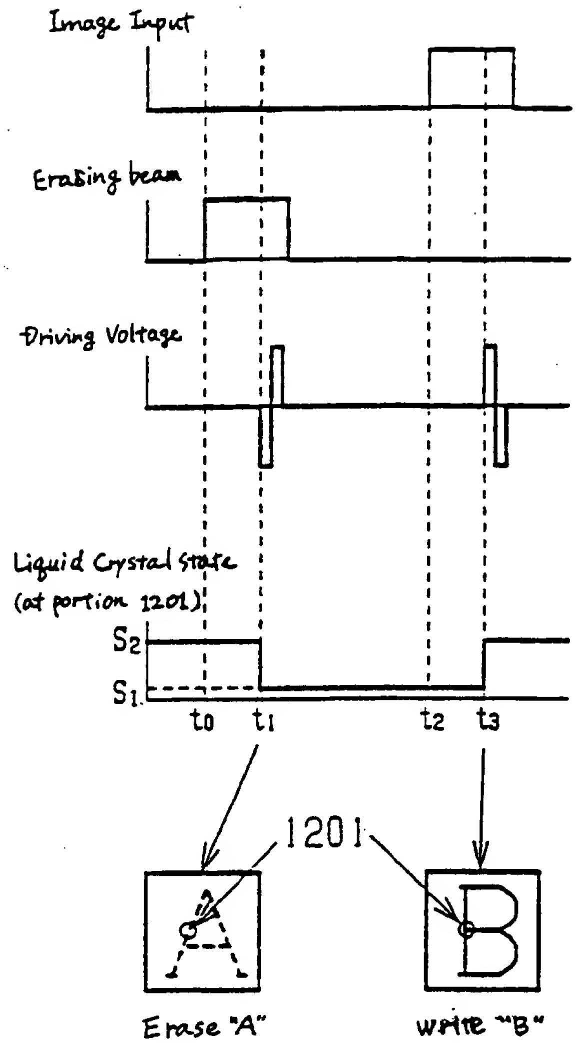
Image Input
Erasing beam
Driving Voltage
Liquid Crystal State
(at portion 1201)
S2
S1
t0
t1
t2
t3
1201
Erase "A"
write "B"

FIG. 12

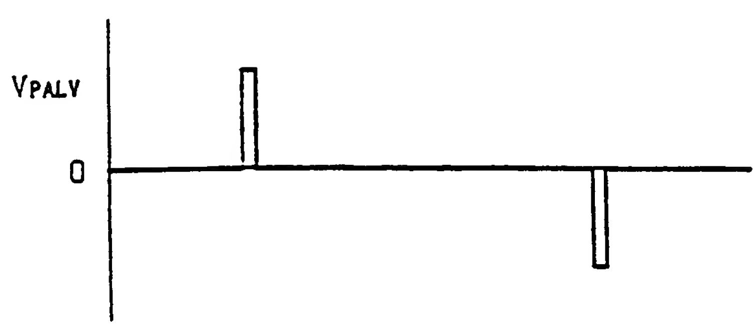
VPALV
0

FIG. 13

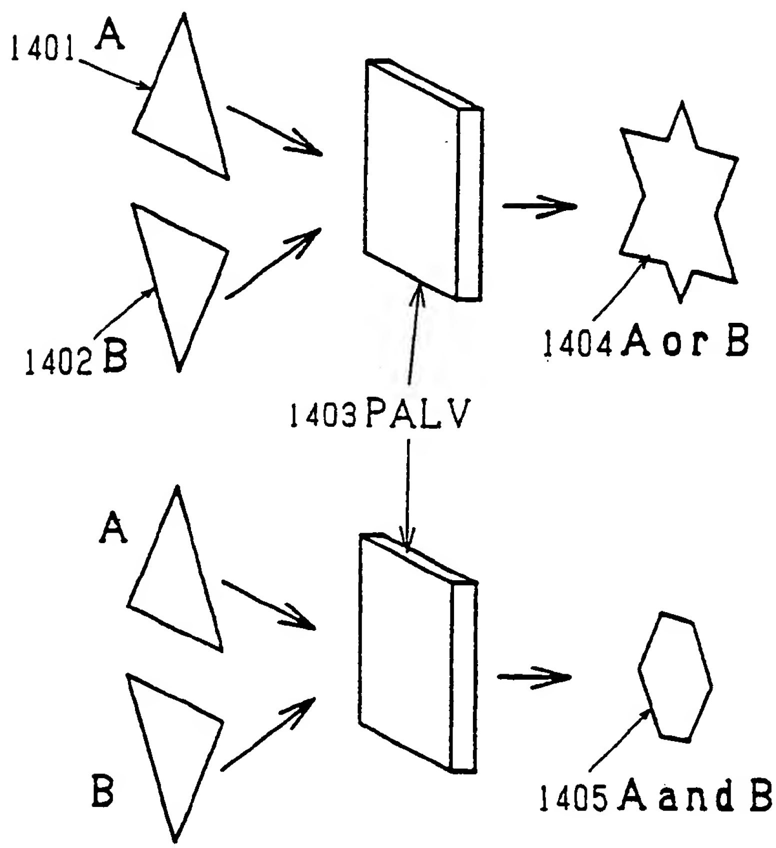

FIG. 14

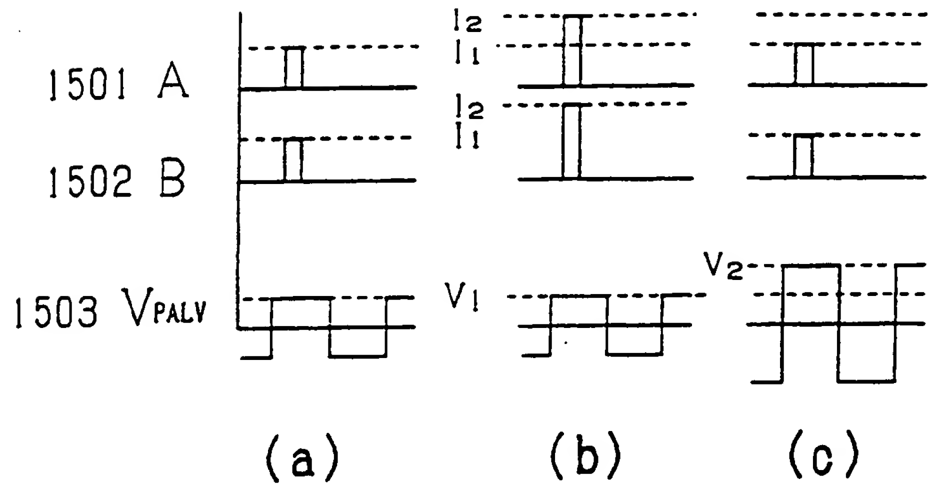
1501 A
1502 B
1503 VPALV
I2
I1
I2
I1
V1
V2
(a)
(b)
(c)

FIG. 15

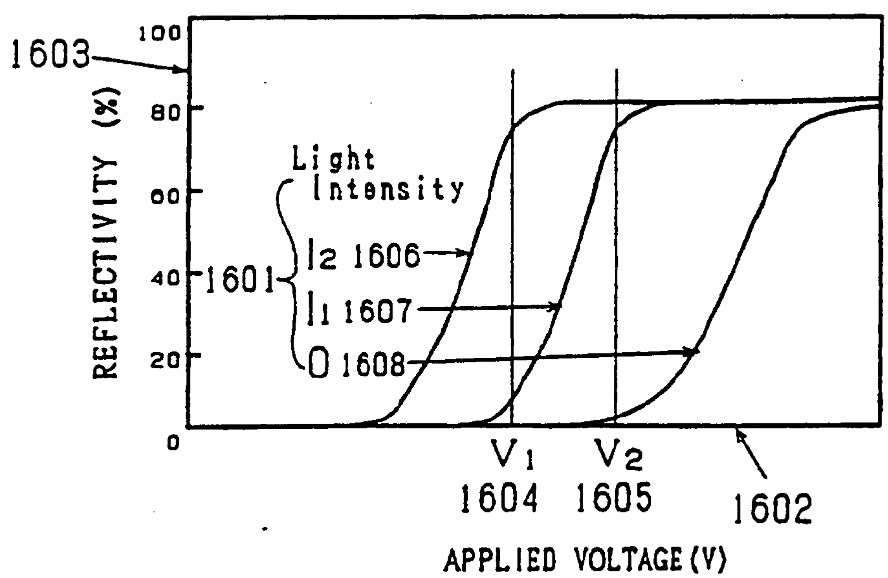
1603
100
80
60
40
20
0
REFLECTIVITY (%)
Light Intensity
1601
I2 1606
I1 1607
0 1608
V1
1604
V2
1605
1602
APPLIED VOLTAGE (V)

FIG. 16

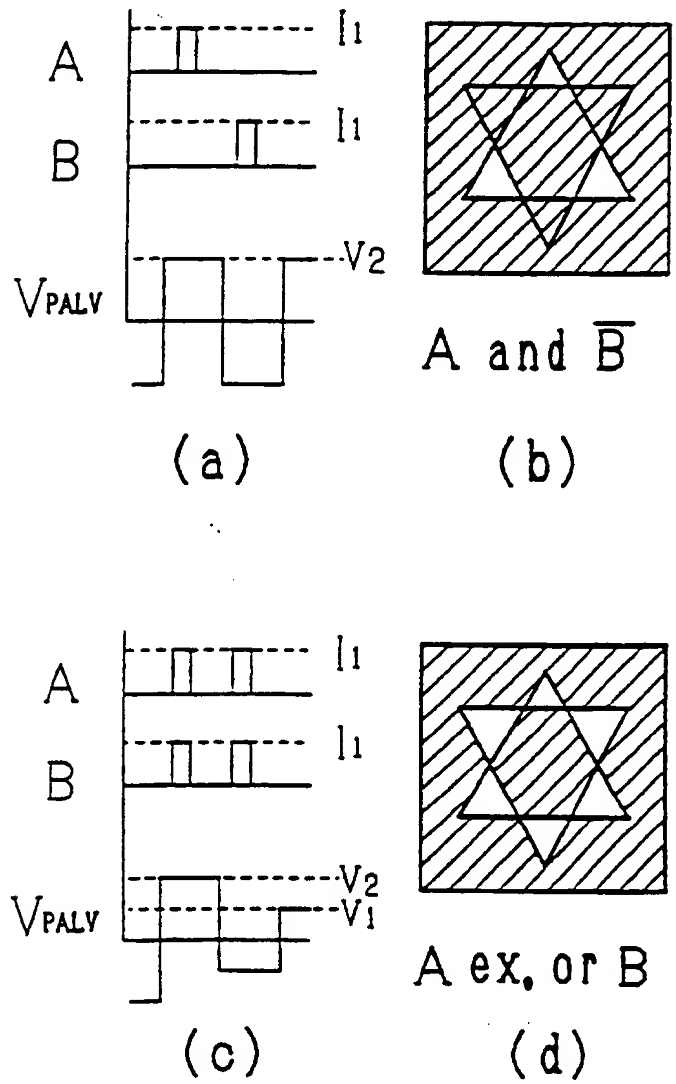

FIG. 17

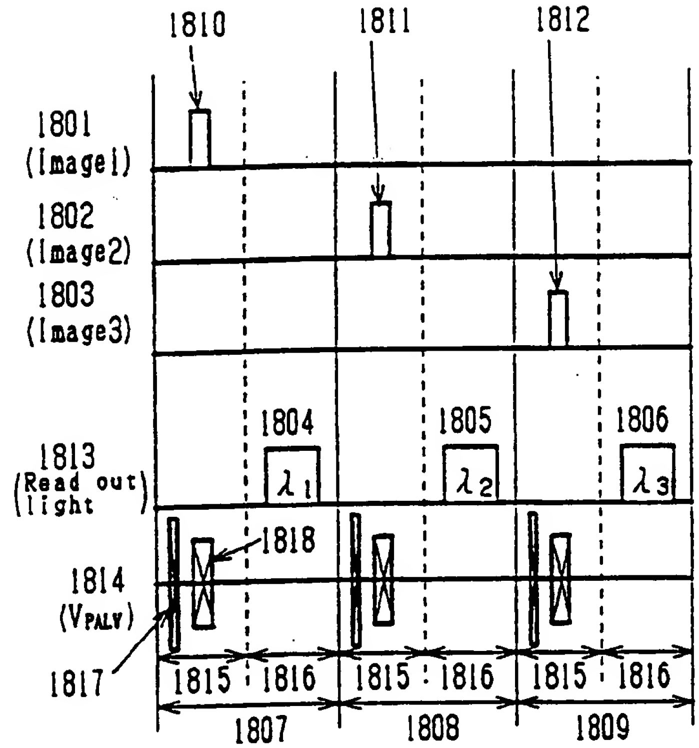
1810
1811
1812
1801
(Image1)
1802
(Image2)
1803
(Image3)
1804
1805
1806
λ1
λ2
λ3
1813
(Read out light)
1818
1814
(VPALV)
1817
1815
1816
1807
1808
1809

FIG. 18

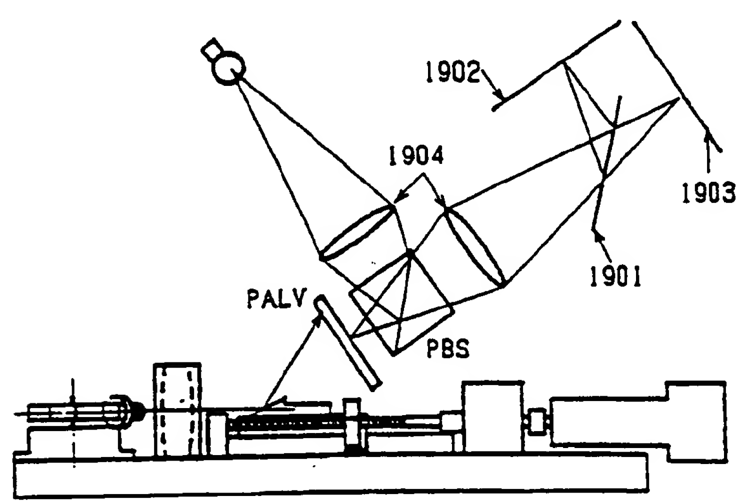
1902
1904
1903
1901
PALV
PBS

FIG. 19